



# Supplementing Biomechanical Modeling with EMG Analysis

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# Problem Statement



- Given the small size of the Multi-Purpose Crew Vehicle (MPCV) exercise device, will it be able to provide sufficient physiological loading to maintain musculoskeletal performance?
- Advanced Exercise Concepts Project Risk:
  - (EM2ED-003) The single-strap design will not allow for exercises to be performed as specified in the functional requirements document (AEC-REQ-001)
- Advance Exercise Concepts Project Requirement:
  - [MPCV-AEC29] Required Resistive Exercises: the device shall allow the crew member to perform squat, deadlift and heel raise exercises with proper body positioning (according to JSC-29558, "Resistive Exercise Description Document")
- OpenSim biomechanical modeling performed to inform risk mitigation

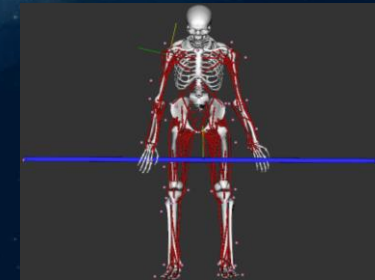




# Biomechanical Models in OpenSim



- OpenSim is open source biomechanical simulation software (<https://simtk.org/home/opensim>)
  - For development of musculoskeletal models
  - For dynamic simulations of movement and kinematics
  - For estimating muscle and joint kinetics
- DAP uses a modified version of the Arnold (2010) lower body model (Gallo, 2016)
- Biomechanical modeling process
  - Experimental kinematic and kinetic data used as input
  - OpenSim biomechanical models used to estimate joint torques and muscle forces



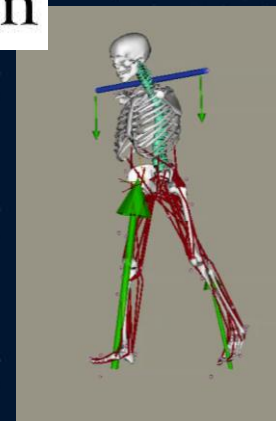
Deadlift



Squat



Heel Raise



Single Leg Squat

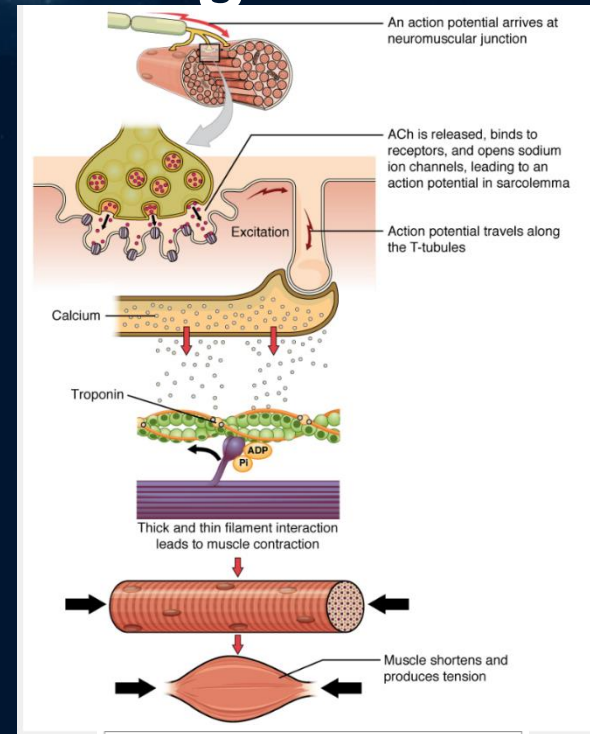




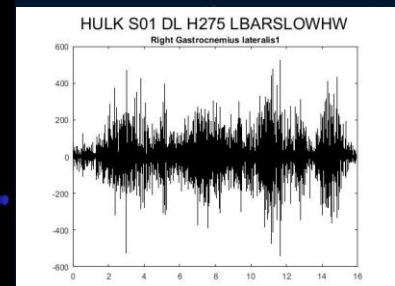
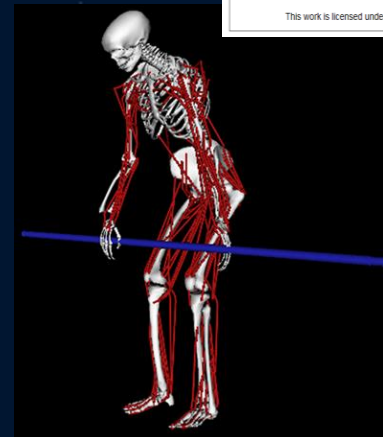
# EMG Supplementing Biomechanical Modeling



- EMG – Electromyography – A record of the electrical potential generated by activated muscle cells
- EMG data will be used to increase the credibility of the OpenSim models
  - Through validation of calculated muscle activity
  - By increasing the input data pedigree
- Data use within OpenSim:
  - As constraints in the calculation of muscle activity
  - As input data instead of calculated muscle activity



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# EMG System in the GRC Exercise Countermeasures Lab



- BTS Free EMG 300
- 16 wireless sensor system
- Smart Capture/Analyzer and EMG Analyzer software
- Muscles recorded:
  - Tibialis Anterior
  - Vastus Medialis
  - Rectus Femoris
  - Vastus Lateralis
  - Hip Adductor
  - Rectus Abdominis
  - External Obliques
  - Medial Gastrocnemius
  - Lateral Gastrocnemius
  - Semitendinosus
  - Biceps Femoris
  - Gluteus Maximus
  - Multifidus
  - Longissimus
  - Middle Trapezius
  - Upper Trapezius

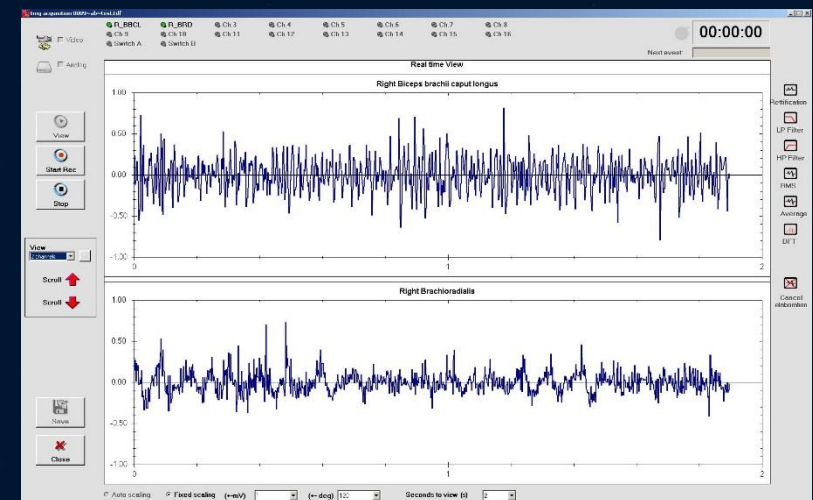
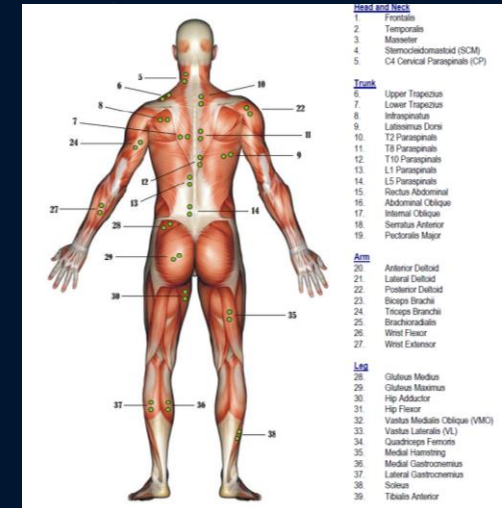




# EMG Data Collection Procedure



- Muscles active during each exercise were selected for recording and verified with a literature search
- Sensor location determined from <http://seniam.org> and the Thought Technology Ltd. surface EMG placement guide
- Signal strength was verified to determine correct sensor placement



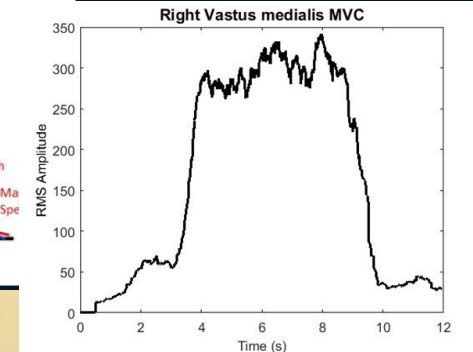
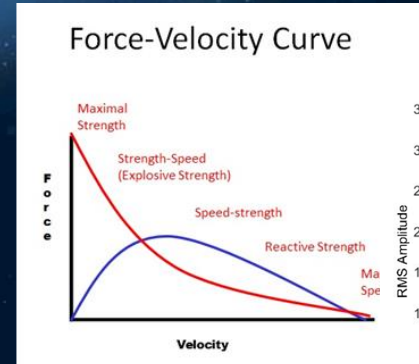




# Maximum Voluntary Contraction



- EMG collected during ~5s Maximum Voluntary Contraction (MVC) for each muscle
- Muscle produces maximum force during isometric, 0 velocity contractions
- MVC used to normalize EMG signals from exercise trials





# Test Variables



- Exercises
    - Squat (SQ)
    - Deadlift (DL)
    - Heel Raise (HR)
    - Single-leg squat (SLS)
  - Stance Variation (Controlled with foot markings)
    - Shoulder width (SQ)
    - Restricted to 21" (SQ)
    - Hip width (DL)
    - Sumo (DL)
    - Toes pointed in (HR)
    - Toes pointed out (HR)
    - Free foot forward (SLS)
    - Free foot back (SLS)
  - Loading Configurations
    - Free weight
    - Long bar
    - Yo-yo Harness (SQ, HR, SLS)
    - T-Bar (DL, HR)
    - Glenn Harness
  - Cadence (Controlled with metronome)
    - 4s (SQ, DL, SLS)
    - 2.5s (SQ, DL, SLS)
    - 2s (HR)
    - 1s (HR)
  - External Load
    - Body Weight
    - Low – 10-12 rep max load
    - Medium - 6-9 rep max load
    - Heavy – 3-5 rep max load
- Exercises performed according to JSC 29558, Resistive Exercise Description Document and an experienced athletic coach monitored subject form





# Variables Compared in this Presentation



- Compare EMG time course and amplitude between different test cases
  - Deadlift
    - Free weight
    - HULK one-point loading with T-bar
  - Squat
    - Free weight
    - HULK one-point loading with Yo-yo harness

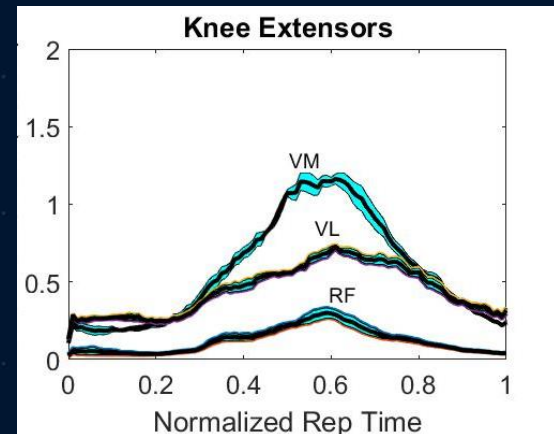
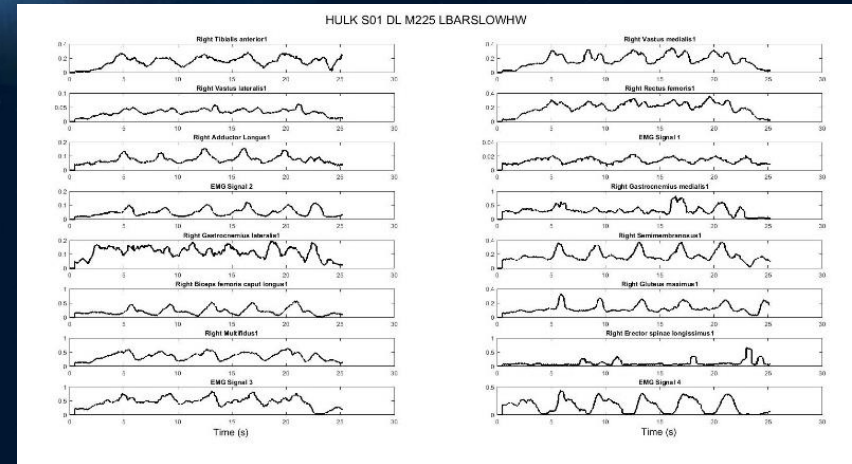




# EMG Data Processing Procedure



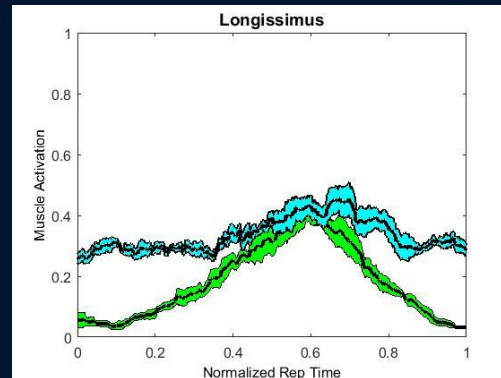
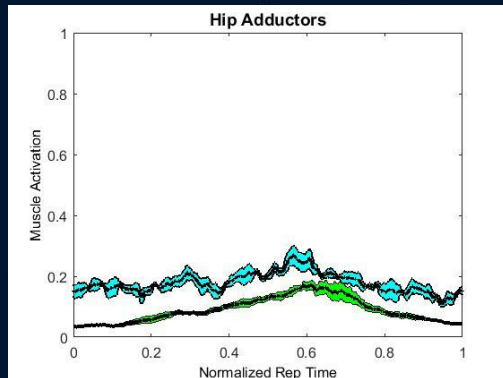
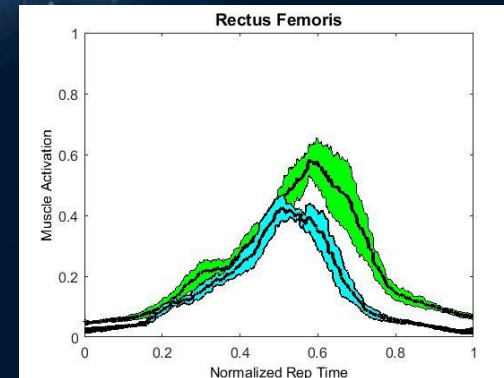
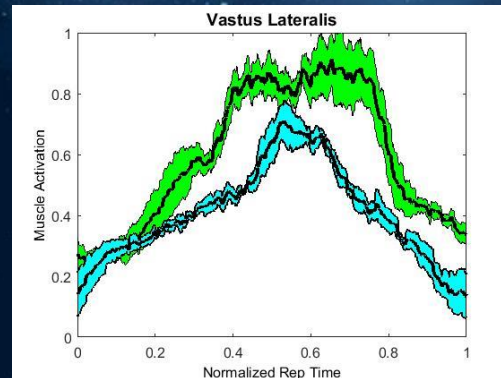
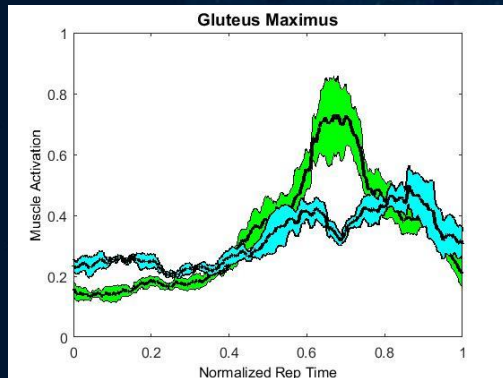
- DC component removal and bandpass filter (20 – 450 Hz)
- Rectify and envelop signal with RMS calculation, using a 250 ms window
- Normalize to MVC
- Break signal into repetitions
- Determine the time-normalized, average repetition, with a  $\pm$  standard error band around the average
- Determine average, peak and integrated EMG for each repetition





- Merletti, Standard for reporting EMG data, *J Electromyogr Kinesiol*, 9:III-IV, 1999.
- Piitulainen et al., Multi-channel electromyography during maximal isometric and dynamic contractions, *J Electromyogr Kinesiol*, 23, 302-310, 2013.
- Browning et al., The effects of adding mass to the legs on the energetics and biomechanics of walking, *Med Sci Sports Exerc*, 39(3) 515-525, 2007.
- DeWitt et al., Kinematic and electromyographic evaluation of locomotion on the enhanced zero-gravity locomotion simulator: A comparison of external loading mechanisms, NASA/TP-2007-214764.

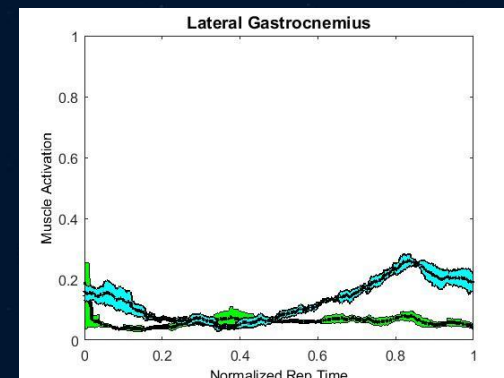
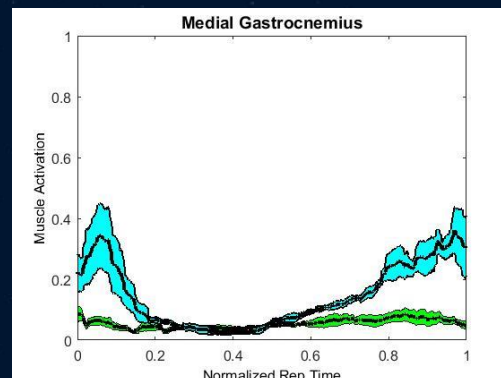
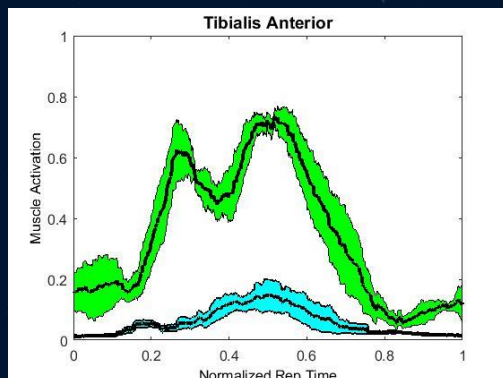


# Results - Squat



 Free Weight

 HULK and Yo-yo Harness



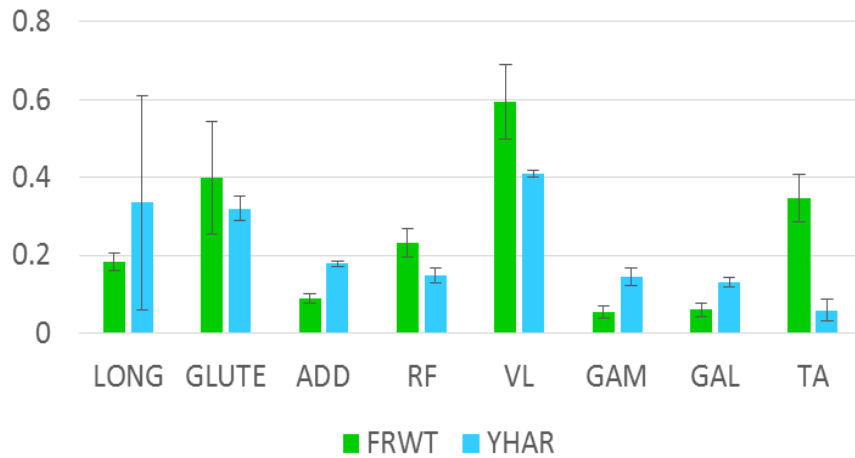




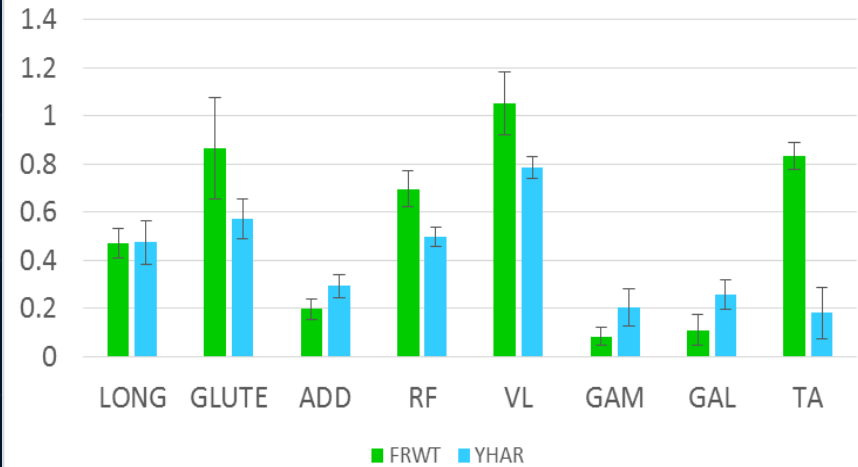
# Summary Graphs - Squat



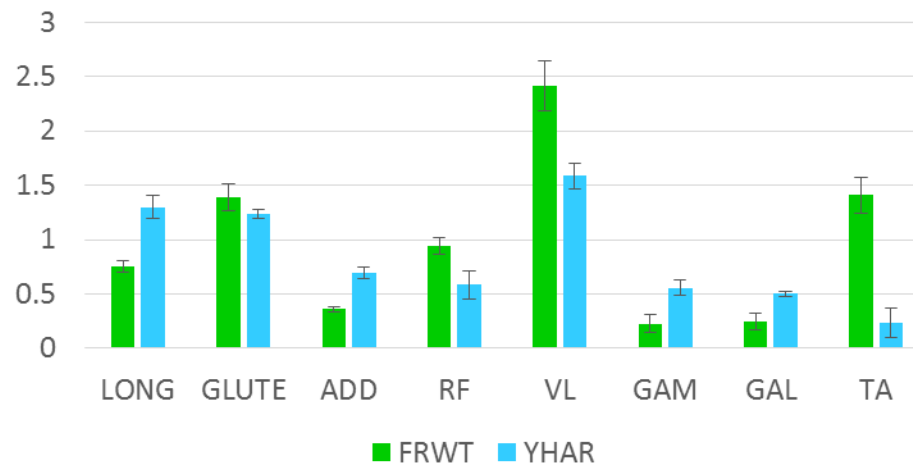
Mean Activation Squat



Peak Activation Squat

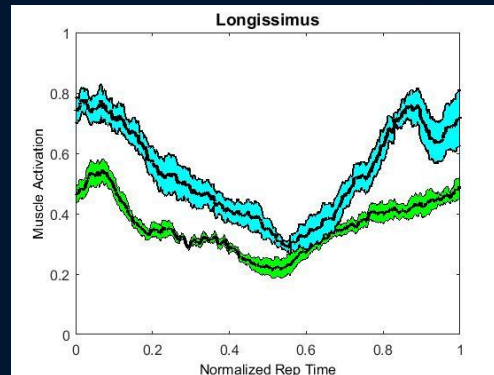
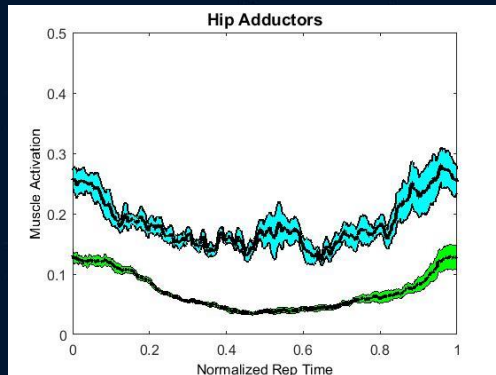
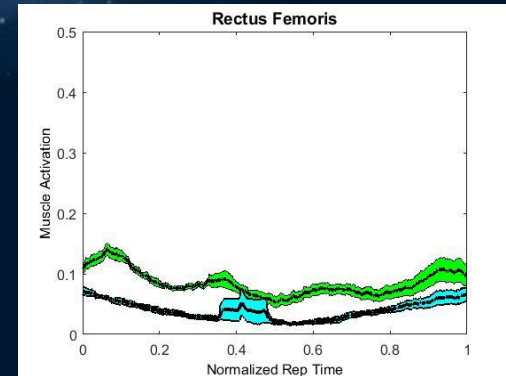
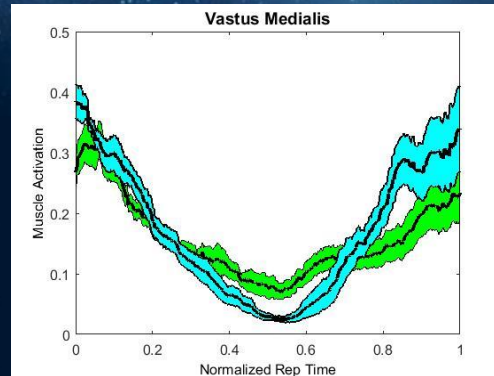
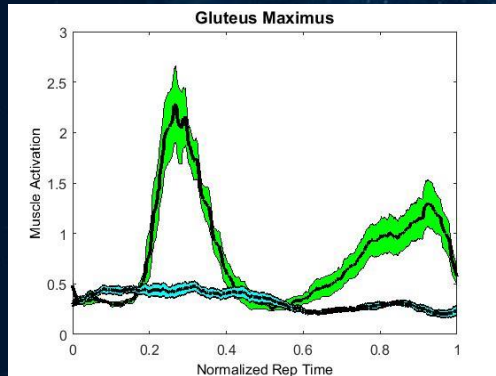



iEMG Squat




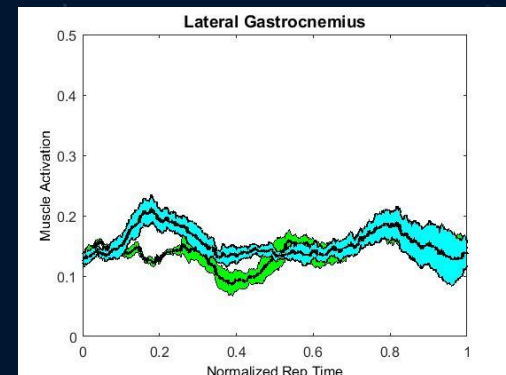
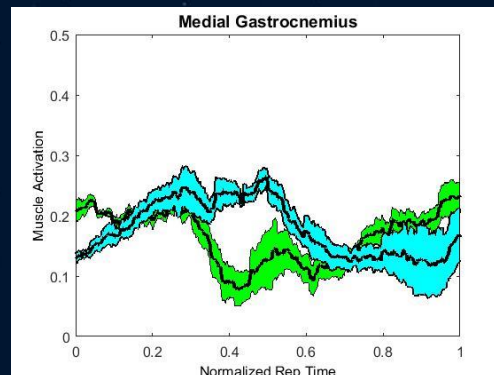
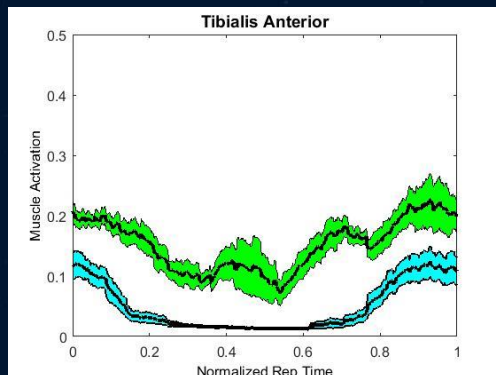


# Results - Deadlift



 Free Weight

 HULK and T-Bar

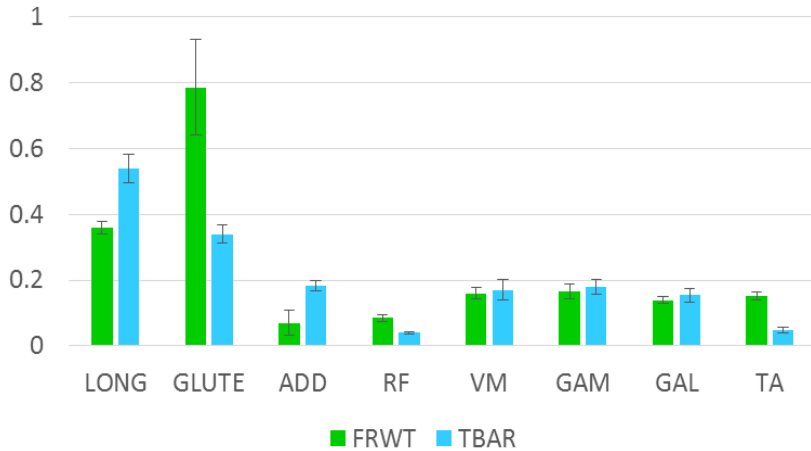




# Summary Graphs - Deadlift



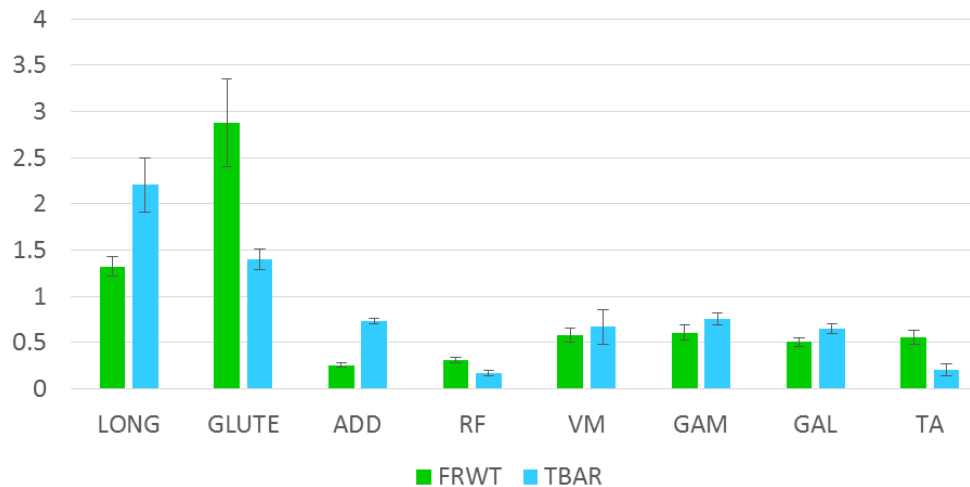
Mean Activation Deadlift



Peak Activation Deadlift



iEMG Deadlift







# Discussion



- Differences in muscle activation observed when exercise is performed with free weights vs. a single-strap exercise configuration
- Limitations with EMG analysis
  - Only one subject used
  - EMG data collected across days
  - MVC not achieved in all cases
- Differences should be explored further to determine their significance
  - Through the full biomechanical analysis currently underway
  - Through a review of the results by subject matter experts
- The full biomechanical analysis is informing the AEC project risk by providing a means of early evaluation





**Thank you**

**Questions?**